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Title: LUNA Condition Based Monitoring Update: Reducing the number of Sensors for Excess Load and External Leak

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LUNA Condition Based Monitoring Update:
Reducing the number of Sensors for Excess Load and External Leak

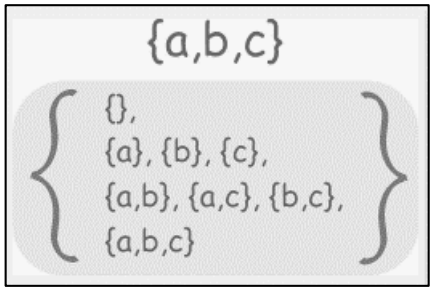
Presented 5/18/2021

Andre Green

Eleak & Eload | Reducing the Number of Sensors

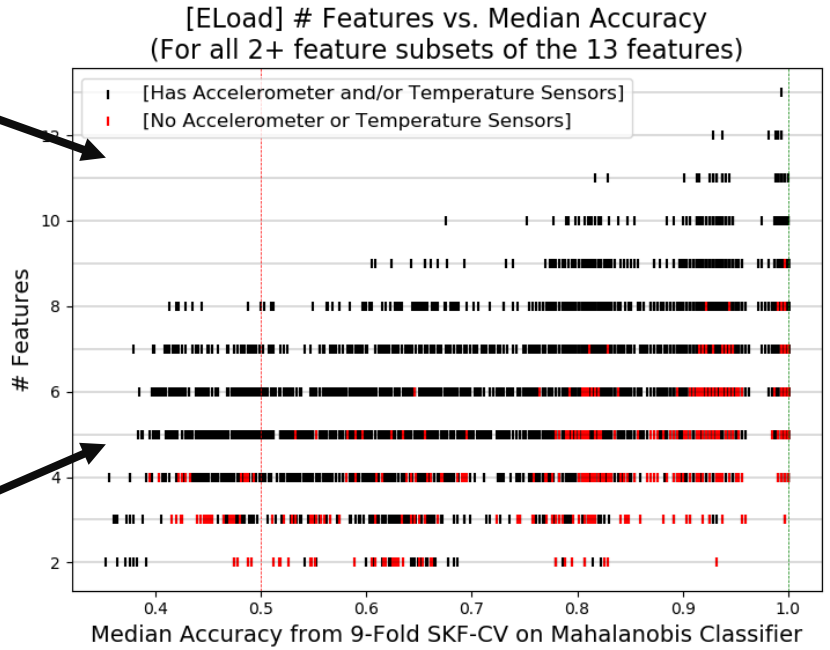
All Usable Subsets of the Set of Features

(For 13 features, there are ~8,192 [2^13] subsets)



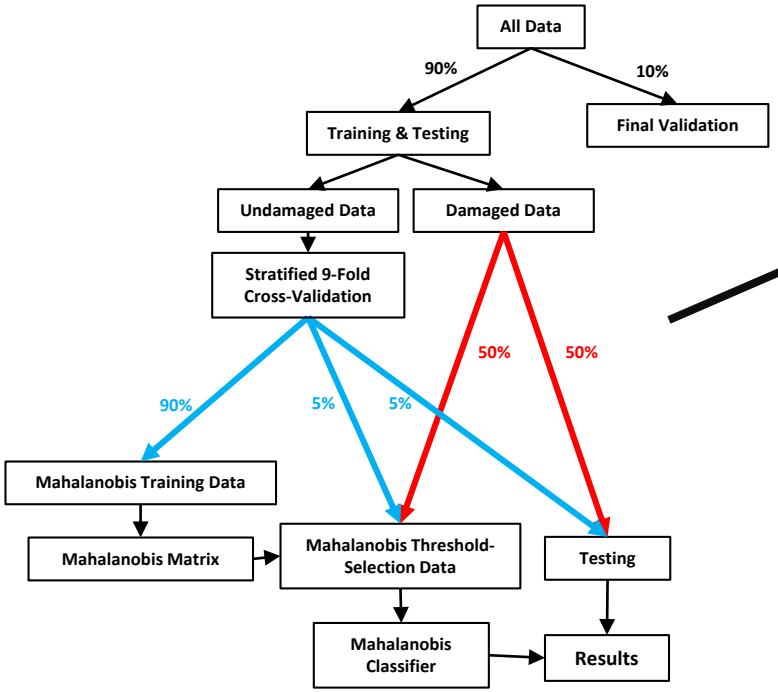
Median Performance of Each Feature Subset

# of Features vs. Median Accuracy



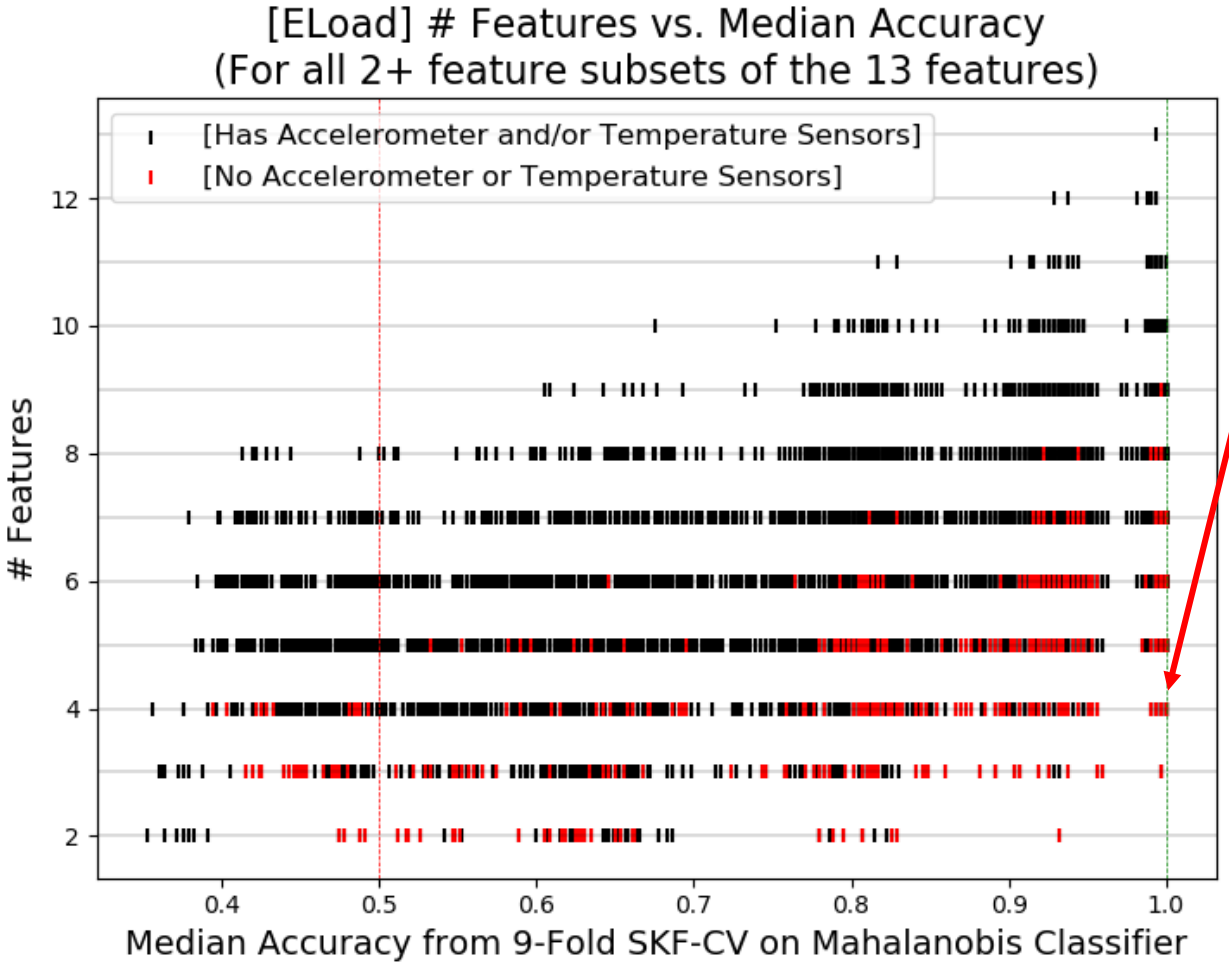
Mahalanobis Classifier

Construction & Testing Process



Each point on the scatterplot represents the median accuracy from the 9 classifiers generated during the 9-fold stratified cross-validation.

ELoad | # Features & Median Accuracy



Red points indicate feature sets which omit accelerometer and temperature sensors. There are several high-performance feature sets for Eload which do not require these sensors.

This slides' graphs and numbers use Eload 000, 300, 375, 480, and 650 as undamaged, and Eload 1200, 1400, 1500, and 1600 as damaged. The 0, 28K, 50K, 75K, 100K, 125K, 150K, 175K and 200K actuation datasets were used.

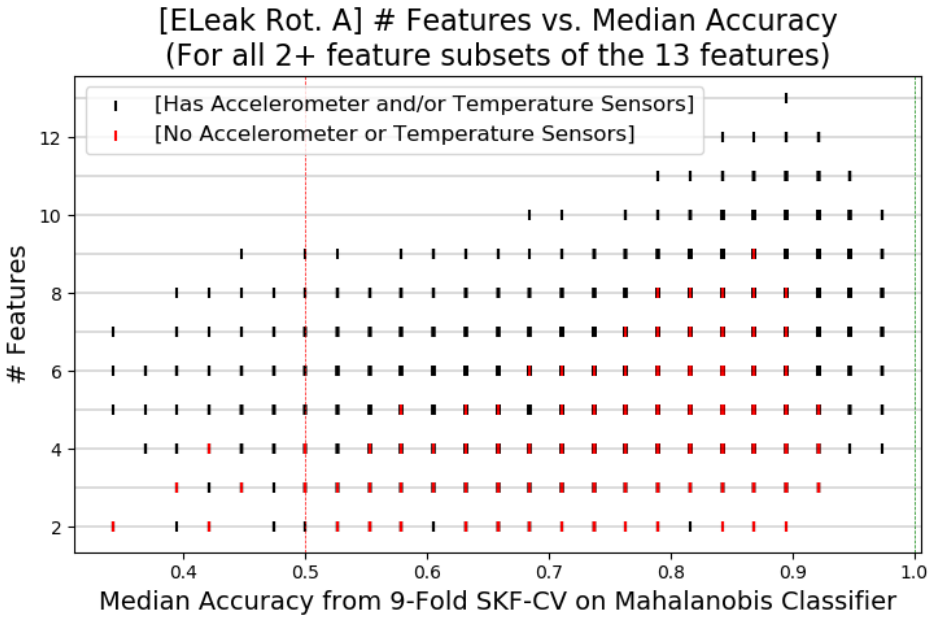
100% Median Accuracy
Small Feature Subsets
[Eload 0-650 considered undamaged, >=1200 damaged]

[3, 4, 6, 7]
[6, 7, 9, 10]
[4, 6, 7, 12]
[6, 7, 9, 12]

Feature Key

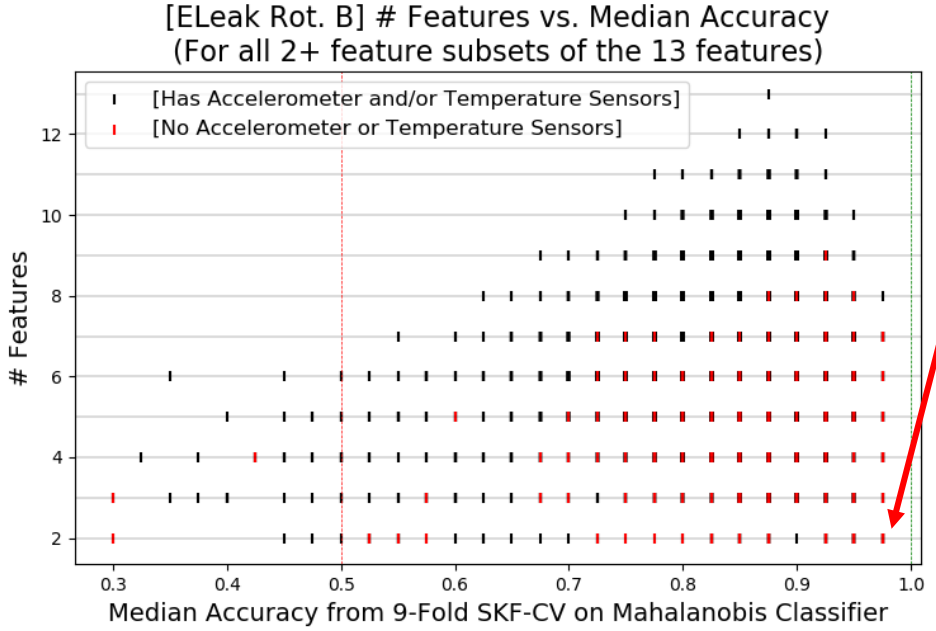
0: 'Var_of_Accel_1',
1: 'Var_of_Accel_2',
2: 'Var_of_Accel_3',
3: 'Mean_of_PG_1',
4: 'Mean_of_PG_2',
5: 'Mean_of_PG_3',
6: 'Var_of_PG_1',
7: 'Var_of_PG_2',
8: 'Var_of_PG_3',
9: 'Slope_of_Angle',
10: 'Pressure_Diff_Sum',
11: 'Diff_Temp_Var',
12: 'Pressure_Max'

ELeak | # Features & Median Accuracy



For the difficult rotation (rotation A), accelerometer and/or temperature data is required to get above approximately 93%.

For the easier rotation case (Rot B, angle < median), there are several feature subsets which give 97.5% accuracy on the tested data, using Eleak 005, 010, 020 and 050 as 'undamaged' and Eleak 100 & 150 as 'damaged'.



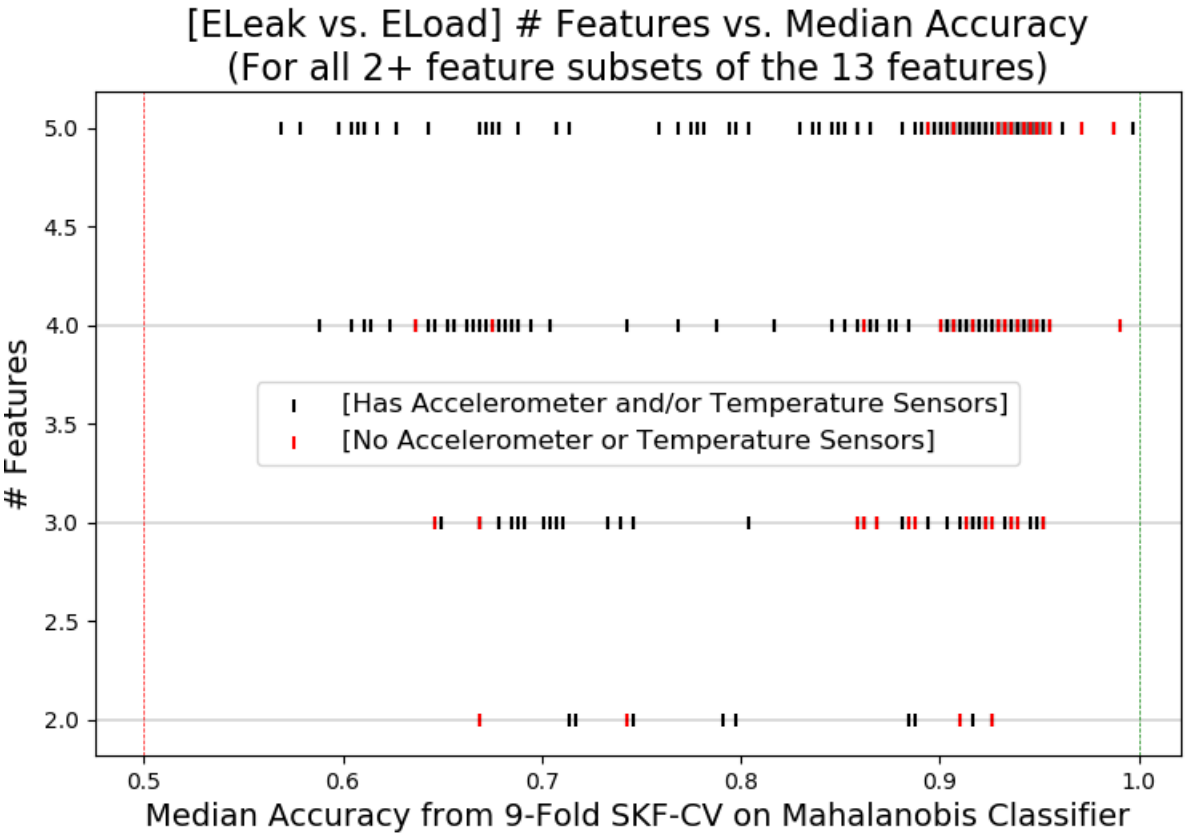
Rot. B 97.5% Median Accuracy
Small Feature Subsets
[ELeak 0-50 considered undamaged, >=100 damaged]

[6, 7] 0.975
[4, 12] 0.975
[6, 12] 0.975
[7, 12] 0.975
[3, 7, 12] 0.975
[3, 4, 7, 12] 0.975
[3, 6, 7, 12] 0.975
[4, 6, 7, 12] 0.975
[10, 12] 0.975
[3, 10, 12] 0.975
[3, 7, 10, 12] 0.975

Feature Key

0: 'Var_of_Accel_1',
1: 'Var_of_Accel_2',
2: 'Var_of_Accel_3',
3: 'Mean_of_PG_1',
4: 'Mean_of_PG_2',
5: 'Mean_of_PG_3',
6: 'Var_of_PG_1',
7: 'Var_of_PG_2',
8: 'Var_of_PG_3',
9: 'Slope_of_Angle',
10: 'Pressure_Diff_Sum',
11: 'Diff_Temp_Var',
12: 'Pressure_Max'

Eleak Rot. B vs. ELoad | # Features & Median Accuracy



The above graph shows the median performance of each subset for separating Eload from Eleak (rotation B), using only subsets of 2-5 features and dropping ½ of the possible subsets to make computation faster. The full calculation (over all usable subsets) is currently running.

99% Median Accuracy
Small Feature Subset
Discerning Eload (any severity) from Eleak Rotation B (any severity)

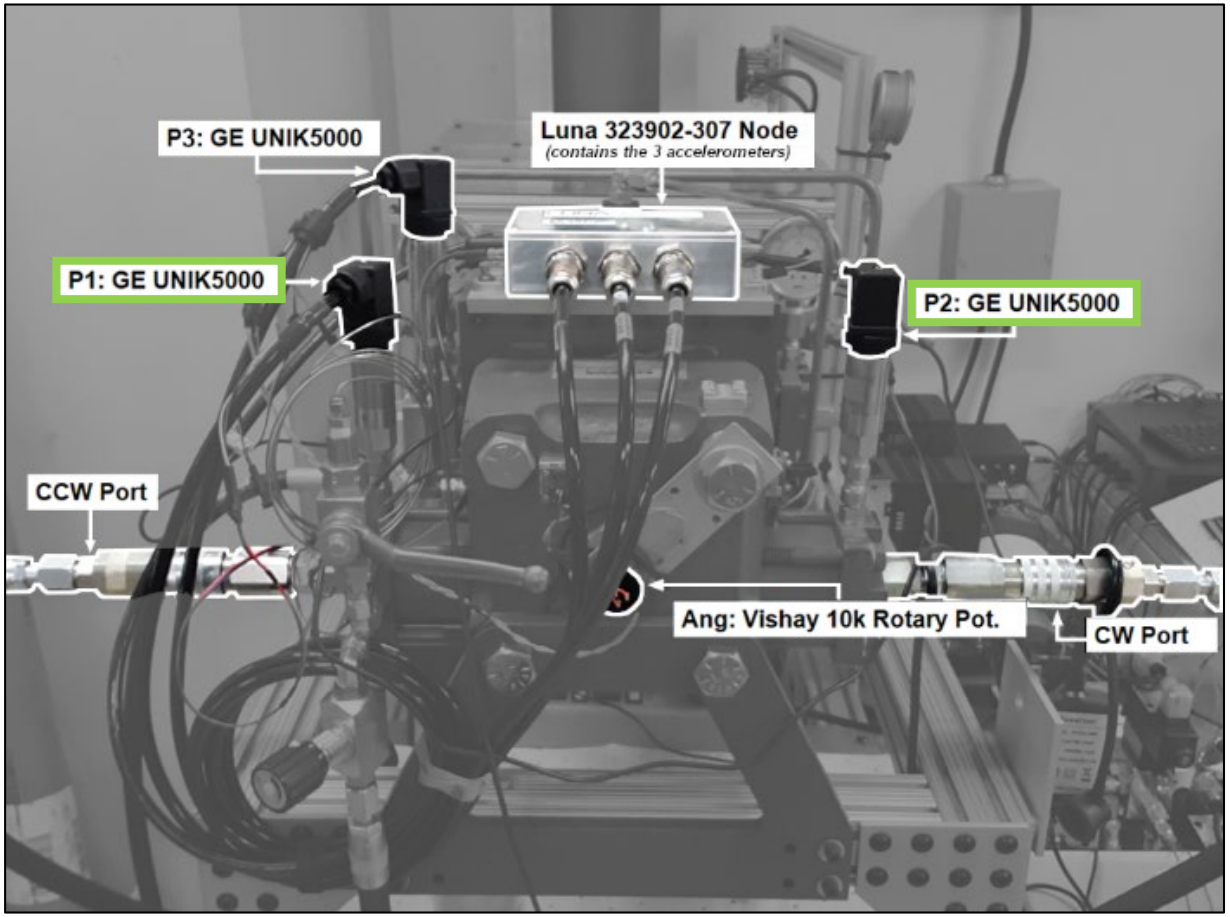
[4, 6, 10, 12], 0.99

All of the features in this subset are derived solely from pressure gauges 1 and 2.

Feature Key

0: 'Var_of_Accel_1',
1: 'Var_of_Accel_2',
2: 'Var_of_Accel_3',
3: 'Mean_of_PG_1',
4: 'Mean_of_PG_2',
5: 'Mean_of_PG_3',
6: 'Var_of_PG_1',
7: 'Var_of_PG_2',
8: 'Var_of_PG_3',
9: 'Slope_of_Angle',
10: 'Pressure_Diff_Sum',
11: 'Diff_Temp_Var',
12: 'Pressure_Max'

Eleak & Eload | Reducing the Number of Sensors



*For Eload and one of Eleak's rotation directions, **>97%** accuracy can be achieved (contingent on the threshold considered 'damaged') with just pressure gauges 1 and 2 (highlighted in green), if the type of damage is known.*

Binary Classification Accuracy

(Damaged/Undamaged)

Eload

[3, 4, 6, 7] -> **100%** Median accuracy
[PG1 mean, PG2 mean, PG1 variance, PG2 variance]

ELoad <= 650: Undamaged
ELoad >= 1200: Damaged

Eleak (Rotation B)

[6, 7] -> **97.5%** Median accuracy
[PG1 variance, PG2 variance]

Eleak <= 050: Undamaged
Eleak >= 100: Damaged

Mahalanobis Convex-Hull Classifier